**Claims**

**1**. A method for compensating for subject-specific variability in an apparatus intended for non-invasively determining the amount of at least two light-absorbing substances in the blood of a subject and provided with emitter means for emitting radiation at a minimum of two different wavelengths and with detector means for receiving the radiation emitted, the method comprising the steps of

- calibrating the apparatus using a nominal calibration,
- carrying out initial characterization measurements, said measurements to include measuring radiation received by the detector,
- based on the characterization measurements, establishing nominal characteristics describing conditions under which the nominal calibration is used,
- storing reference data indicating the nominal characteristics established,
- performing in-vivo measurements on a living tissue, wherein radiation emitted through the tissue and received by the detector means is measured,
- based on the in-vivo measurements and the reference data stored, determining tissue-induced changes in the nominal characteristics, and
- compensating for subject-specific variation in the in-vivo measurements by correcting the nominal calibration on the basis of the tissue-induced changes.

**2**. A method according to claim **1**, including compensation for effects causing wavelength shift.

**3**. A method according to claim **1**, including compensation for effects internal to the tissue.

**4**. A method according to claim **1**, including both compensation for effects causing wavelength shift and for effects internal to the tissue.

**5**. A method according to claim **2**, wherein the compensation for effects causing wavelength shift includes defining subject-specific extinction coefficients for the substances.

**6**. A method according to claim **3**, wherein the compensation for effects internal to the tissue includes defining a subject-specific transformation used to transform in-vivo measurement results to the Lambert-Beer model.

**7**. A method according to claim **4**, wherein the compensation for effects causing wavelength shift includes defining subject-specific extinction coefficients for the substances, and the compensation for effects internal to the

tissue includes defining a subject-specific transformation used to transform in-vivo measurement results to the Lambert-Beer model.

**8**. A method according to claim **5**, wherein said establishing step includes determining DC transmission characteristics of the emitter and detector means, spectral characteristics of the emitter and detector means and nominal transmission characteristics for the tissue.

**9**. A method according to claim **8**, wherein said establishing step further includes determining the temperature in which the nominal calibration is used.

**10**. A method according to claim **9**, wherein the extinction coefficients $\varepsilon_{I,j}$ are determined according to the following formula:

$$\varepsilon_{ij}^{effective} = \frac{1}{W} \int_{\Delta\lambda} \varepsilon_j(\lambda) * LED_i(\lambda(T)) * DET(\lambda) * tissue(\lambda) \partial\lambda ,$$

where the integration is over the emission spectrum $LED_i(\lambda)$ of the emitter means, $DET(\lambda)$ represents the spectral sensitivity of the detector means, $tissue(\lambda)$ is the spectral transmission of radiation through the tissue, $\varepsilon_j$ is the extinction coefficient of the substance, $T$ is the temperature, and $i$ and $j$ are matrix indices.

**11**. A method according to claim **10**, wherein

- the step of establishing nominal characteristics includes defining a nominal extinction matrix with a nominal extinction coefficient for each substance/wavelength pair, and

- the step of determining tissue-induced changes includes updating the nominal extinction matrix, whereby the updated matrix includes the subject-specific extinction coefficients to be used in the Lambert-Beer model.

**12**. A method according to claim **11**, wherein the nominal extinction matrix is determined according to the following formula

$$\varepsilon_{ij}^{effective} = \frac{1}{W} \int_{\Delta\lambda} \varepsilon_j(\lambda) * LED_i(\lambda(T)) * DET(\lambda) \partial\lambda$$

where the integration is over the emission spectrum $LED_i(\lambda)$ of the emitter means, $DET(\lambda)$ represents the spectral sensitivity of the detector means; $\varepsilon_j$ is the extinction coefficient of the substance, $T$ is the temperature, and $i$ and $j$ are matrix indices.

**13**. A method according to claim **11**, wherein the step of establishing nominal characteristics further includes determining a first shift matrix, the elements of which indicate a relative change in each extinction coefficient,

assuming that the slope of the term *tissue*(λ) has a fixed value deviating from zero.

**14**. A method according to claim **13**, wherein the step of determining tissue-induced changes in the nominal characteristics includes defining (1) the slope of the term *tissue*(λ) and (2) the subject-specific extinction coefficients based on the shift matrix and the slope defined.

**15**. A method according to claim **6**, wherein the method further includes the steps of

- storing an average transformation measured for a great number of subjects and

- based on the tissue-induced changes, updating the average transformation, whereby the updated transformation represents the subject-specific transformation.

**16**. A method according to claim **10**, wherein

- the step of establishing nominal characteristics further includes defining temperature dependence of the emitter and detector means, and

- said compensating step includes temperature compensation for the emitter and detector means.

**17**. A method according to claim **16**, wherein the step of establishing nominal characteristics further includes determining a second shift matrix the elements of which indicate a relative change of each extinction coefficient for a predetermined wavelength shift.

**18**. A method according to claim **17**, wherein the step of determining tissue-induced changes in the nominal characteristics includes

- defining a wavelength shift caused by temperature and

- defining subject-specific coefficients based on the shift matrix and the wavelength shift defined.

**19**. A method according to claim **7**, wherein

- the step of defining nominal characteristics includes calculating nominal values for the Functional Light Transmission (FLT) of the apparatus,

- the step of determining tissue-induced changes includes calculating new values for the Functional Light Transmission (FLT) of the apparatus, and

the step of compensating includes determining the subject-specific transformation on the basis of the nominal and new values.

**20**. A method according to claim **7**, wherein

- the step of defining nominal characteristics includes calculating nominal values for function $F_{kl}$ of the apparatus,

- the step of determining tissue-induced changes includes calculating new values for the function $F_{kl}$ of the apparatus, and

- the step of compensating includes determining the subject-specific transformation on the basis of the nominal and new values,

wherein the function $F_{kl}$ corresponds to the ratio $\dfrac{f_a(\mu_a^k - \mu_v^k) + \mu_v^k}{f_a(\mu_a^l - \mu_v^l) + \mu_v^l}$, where $\mu_v$ and $\mu_a$ are the absorption coefficients of venous and arterial blood, respectively, as determined in the Lambert-Beer domain, $f_a$ is the volume fraction of arterial blood, and the superscripts *k* and *l* indicate the wavelength.

**21**. A method according to claim **20**, wherein the nominal and new values for the Function $F_{kl}$ are calculated on the basis of measured fluctuation of the DC component of the radiation received by the detector means.

**22**. A method according to claim 20, wherein

- the step of determining tissue-induced changes includes calculating a first approximation for the amount of the substances, and

- the step of compensating includes utilizing the first approximation for determining the subject-specific transformation.

**23**. A method according to claim **1**, wherein the at least two light absorbing substances include oxyhemoglobin (HbO2) and reduced hemoglobin (RHb).

**24**. An apparatus for non-invasively determining the amount of at least two light absorbing substances in the blood of a subject, the apparatus comprising

- emitter means for emitting radiation at a minimum of two different wavelengths,

- detector means for receiving said radiation at each of said wavelengths and producing at least two electrical output signals,

- first signal processing means for processing said output signals and producing a modulation signal for each wavelength, each modulation signal representing the pulsating absorption caused by the arterialized blood of the subject,

- second signal processing means for applying a predetermined calibration on said modulation signals, whereby transformed modulation signals applicable in the Lambert-Beer model are obtained,

- memory means for storing reference data indicating nominal characteristics under which said predetermined calibration has been applied,

- first compensation means, operatively connected to the memory means, for determining tissue-induced changes in the nominal characteristics,

- second compensation means, operatively connected to the first compensation means, for defining a subject-specific calibration by correcting the predetermined calibration on the basis of the tissue-induced changes, and

- calculation means, responsive to the second compensation means, for determining said amounts.

**25**. A sensor for collecting measurement data for a pulse oximeter intended for non-invasively determining the amount of at least two light absorbing substances in the blood of a subject, the sensor comprising

- means for emitting radiation at a minimum of two different wavelengths,

- means for receiving said radiation at each of said wavelengths and producing at least two electrical output signals,

- storage means including reference data indicating nominal characteristics describing calibration conditions of the pulse oximeter, said data allowing an apparatus connected to the sensor to determine tissue-induced changes in the nominal characteristics when radiation is emitted through said tissue.

**26**. A sensor according to claim **25**, wherein the means for emitting radiation are Light Emitting Diodes.

**27**. A sensor according to claim **25**, wherein the means for emitting radiation are lasers.

**28**. A sensor according to claim **25**, wherein the means for emitting radiation include radiation conduction means for conducting radiation from the emitting component to the tissue site, at which the measurement is performed.

**29**. A sensor according to claim **25**, wherein the means for receiving radiation include radiation conduction means for conducting radiation from the tissue site to the detector component.

**30**. A sensor according to claim **25**, wherein the reference data includes the Functional Light Transmission (FLT) of the apparatus.

**31**. A sensor according to claim **25**, wherein the reference data includes function $F_{kl}$ of the apparatus in nominal conditions,

wherein the function $F_{kl}$ corresponds to the ratio $\frac{f_a(\mu_a^k - \mu_v^k) + \mu_v^k}{f_a(\mu_a^l - \mu_v^l) + \mu_v^l}$,

where $\mu_v$ and $\mu_a$ are the absorption coefficients of venous and arterial blood,

respectively, as determined in the Lambert-Beer domain, $f_a$ is the volume fraction of arterial blood, and the superscripts $k$ and $l$ indicate the wavelength.